HOSPITAL ELECTRICAL FACILITIES

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FOREWORD

An electrical supply system that is adequate in its distribution and anticipates all foreseeable load conditions is essential to modern hospitals. This is difficult to accomplish because medical and technological advances are bringing increasingly complex electrical and electronic equipment to bear on patient care.

Guidelines for electrical installations for architects and engineers concerned with hospital construction were initially issued in 1949 by the Division of Hospital and Medical Facilities of the Public Health Service and revised in 1952, 1959, 1961, and 1965. In this revision, the guidelines have been rewritten to reflect changes in current practices, to provide up-to-date references to applicable codes and standards, and to conform with recommended design practices that should be followed in the construction of hospital and health facilities.

It is hoped that this publication will be useful to architects, engineers, and others concerned with providing optimum hospital electrical system facilities.

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INTRODUCTION

Electrical energy is the one source of power ıpon which almost every function of the hospital lepends. Electrical power supply to the hospital nust be adequate and dependable, and electrical :quipment utilized in the hospital should be of an pproved type and of the best quality available. If he normal electric service is interrupted, certain quipment should be connected immediately to an mergency service: blood- and bone-bank refrig-rators, respirators, electrical impulse devices ıat stimulate and regulate heart action, and other ritical equipment, including some lighting and ɔme boiler-control equipment. Interruptions of .ectrical power in any part of the hospital will ɜriously interfere with work in that area and may 'fect other areas also.

For adequate patient care, the hospital must ɔerate continuously and always be ready for emer-ɜncies. The functioning of the hospital on a 24-ıur basis, made possible by electrical services, quires the use of top quality equipment through-t to afford the highest dependability. To imple-ɜnt this dependability, design, construction, and ɔeration of these service facilities should be ovided by, or under the direction of, top quality ɜctrical engineers in these respective fields.

Data show that the overall cost of operating a hospital for 3 years is approximately equal to the total construction cost of the hospital for similar labor and wage conditions. Although cost data on the electrical system alone are difficult to obtain, available data indicate that emphasis should be placed on design of an electrical system that will operate economically and provide for easy maintenance, rather than only on the least possible installation cost. Careful design, good construction, and the use of readily available high-grade standard types of materials that are best suited for each purpose will assure minimum operating and maintenance costs. Contract costs of electrical equipment and installations in hospitals of conventional design, using fossil-fuel-fired boilers for heating, exclusive of elevators, are about 14 percent of the total construction costs. The use of mobile electrical and electronic equipment will add approximately 7 percent to the costs.

Studies by the U.S. Public Health Service indicate that noise in hospitals disturbs patients to a degree that may retard or interfere with their recovery. Because many objectionable noises are caused by electrical and mechanical equipment, care should be exercised in the design, specifications, and location of equipment so as to minimize such noises.

CODES AND STANDARDS

In general, all electrical service lines, equip-nt, and connections should conform to current :ions of applicable national codes and to the local es if their requirements exceed those of the :onal codes.

A listing of the national codes and standards licable to hospitals and health facilities is given eferences 1, 2, and 3.

Some of these codes and standards apply to ıospitals whereas others may not apply in all ɜs. Recommended practices and committee ɔrts, similar in contexture to standards pro-:d by the Illuminating Engineering Society (IES) the Institute of Electrical and Electronics Engineers, Inc., (IEEE) provide reliable and useful information. The codes and standards most frequently used, or referenced, should be readily available to those planning, constructing, or inspecting hospital and health facilities. As a minimum, these should include, but should not be limited to, the following:

Codes and Standards of the National Fire Protection Association (NFPA)

NFPA No. 70, National Electrical Code 2(a)/

NFPA No. 56, Code for the Use of Flammable Anesthetics 2(b)/

NFPA No. 76, Standard for Essential Hospital Electrical Service 2(c)/

NFPA No. 101, Life Safety Code 2(d)/
NFPA No. 78, Lightning Code 2(e)/

Codes of the United States of America Standards Institute (USASI)

A17.1-1965 and Supplement A17.1a, Elevators, Dumbwaiters, and Moving Walks, Safety Code for 3(a)/

A17.2-1960, Elevators, Inspection Manual [illegible]

Y32.9-1962, Architectural and Electrical [illegible] Drawings, Graphic Electrical Wiring Sy[illegible] for 3(d)/

Z10.1-1941, Abbreviations for Scientific an[illegible] gineering Terms 3(e)/

SERVICE MAINS

Main Electrical Service

Consultation with the local utility company concerning the services available, rates, connection points, and conditions to be met is a planning prerequisite to any decision on the voltage and arrangement of feeders to be brought into the building.

The decision as to whether primary or secondary service is to be brought into the building should be based on pertinent local conditions and consideration of advantages and disadvantages of both types, voltage drop, length of secondary feeders, installation cost, maintenance cost, utility rate of power consumed, and insurance rate difference, if any. An underground service usually costs four to eight times that of a conventional overhead service, but often is preferred for hospitals because of landscaping and less probability of service interruptions caused by storms, ice loads, or other overhead disturbances. (See references 1(a) and (m) and 2(a) for codes applicable to utility service lines.)

If primary service is purchased, the hospital must provide, install, and maintain the step-down transformers, switches, disconnectors, and other converting apparatus. The costs of installing and maintaining this equipment are offset in the lower power rate, usually about 20 percent less than that for secondary service.

Frequently, voltage drop at the consuming end of long secondary feeders is compensated for by changing the tap connection of the transformer to provide an overvoltage at the sending end of the feeder. In large or spread-out hospitals, a more economical installation and better operating conditions will result from utilizing two or more transformers, or substations, to minimize the len[illegible] of low-voltage feeders, thereby maintaining [illegible] voltage regulation.

Overvoltage as well as undervoltage is und[illegible]sirable. For example, a 10 percent overvolt[illegible] reduces filament lamp life to about 75 percent [illegible] decreases power factor of general purpose motors from 0.3 to 0.6 percent; a 10 percent undervoltage decreases filament lamp lighting output about [illegible] percent, affects operating characteristics of mo[illegible]tors (see section on Motors), and may result [illegible] poor or sluggish operation of electrical control devices.

To maintain a nearly constant voltage on low-voltage circuits for light and power, two or more substations will permit shorter feeders and corresponding lesser voltage drop. Also automatic voltage regulators of the air-cooled induction type are sometimes used to maintain a near constant voltage on lightning circuits.

Transformers installed inside the hospital should be indoor types, either nonflammable liquid-immersed or dry type. Open dry-type transformers have less impulse strength than liquid-filled types. They require frequent cleaning and are suitable for indoor use only. Sealed dry-type transformers have many advantages of both the liquid and open dry types, but have the same impulse strength limitations as the open dry-type transformers. However, they are dusttight and weatherproof, can be installed at lower cost, and require less space than liquid types.

The circuit breakers for switching the main secondary circuits are usually the drawout type in larger hospitals or the molded-case type in

smaller hospitals. The drawout type is more expensive to install but provides a higher degree of protection, reliability, and ease of maintenance.

Three-phase, 4-wire 120/208Y-volt distribution systems are generally preferred for small hospitals because of economy and convenience in providing for both single-phase and 3-phase connections at the distribution panels. For operation of large motors, higher voltage is preferred to re-duce feeder and equipment sizes. An intermediate system is the 3-phase, 4-wire 277/480Y-volt sys-tem, using separate transformers of the dry type for 120-volt service. The nominal voltage of any distribution system should be that of an industry standard conforming to USASI Publication C84.1-.954. 3(f)/

Some of these preferred voltages that are ap-licable to hospital distribution systems are given n table 1.

The current-carrying capacity of the service onductors brought into the building should be great nough to carry the maximum demand, or peak ad, without excessive voltage drop.

The maximum demand for hospitals of equal zes may vary considerably because of design, imatic conditions, and method of operation. Dur-g the past few years, the maximum demand per spital bed has increased because of added air-nditioning equipment, new appliances, and im-oved lighting. Estimates of the demand for plan-ng new construction can only be approximate.

The following data may serve as guides in load ecasting for hospital construction: In 1951, de-nd load data on several hospitals grouped ac-rding to size showed that the maximum demand 88 hospitals having an average of 800 beds was 39 kw per bed; for 22 hospitals having an average 350 beds it was 0.38 kw per bed; and for 11 hos-als having an average of 270 beds it was 0.66 kw bed. The greatest demand for any of these pitals was 1.09 kw per bed.

Resurveys of representative groups of these pitals were made six years later to obtain a d in changes in power demands. The following results were obtained. Of the group of hospitals that formerly had an average demand of 0.66 kw per bed, seven showed an average increase in demand of 56 percent. Another group that formerly had an average demand of 0.38 kw per bed showed an increase averaging 68 percent in ten years. The highest demand of any hospital in this group at the time of resurvey was 1.5 kw per bed.

Data supplied in 1959 on 34 hospitals constructed in California show a considerably greater power demand than that reported above. The average demand for these was 1.56 kw per bed, ranging from 0.66 to 3.7 kw per bed. In 7 of these 34 hospitals, the entire building was air conditioned. The power demand in a completely air-conditioned building is about twice that of a nonair-conditioned building.

The 1962 Utilities Survey by the U.S. Public Health Service covering 41 hospitals widely separated geographically in the United States shows that power demands have continued to increase since the initial survey in 1951. This 1962 survey showed that in a modern 200-bed hospital fully air conditioned, with electric cooking, high-speed elevators, laundry, good lighting and other modern electrical services, electric power demands ran as high as 3.9 kw per bed. This figure can be partially broken down as follows: 1.95 kw for air conditioning, 0.78 kw for lighting, and 1.17 kw for other power and motor loads. One-third of the 41 hospitals surveyed were fully air conditioned and had maximum demands averaging 3.0 kw per bed.

A spot check of hospitals in Washington, D.C., and nearby Virginia showed maximum (peak) demands during 1967 as follows:

- Seven general hospitals in Virginia had an average of 2.34 kw/bed for the group, ranging from 1.20 to 3.40 kw/bed.
- One additional all-electric general hospital had a peak demand of 10.92 kw/bed.
- Five general hospitals in Washington, D.C., had an average peak demand of 4.28 kw/bed for the group, ranging from 3.5 to 4.8 kw/bed.

Table 1.--SYSTEM VOLTAGES - AT POINT OF UTILIZATION BY EQUIPMENT

Preferred Base Voltage	Preferred Nominal System Voltage (a)(b)	Voltage Zones Above and Below Preferred Nominal System Voltages: Favorable Zone Minimum	Favorable Zone Maximum	Tolerable Zone (c) Minimum	Tolerable Zone (c) Maximum
120	120	110	125	107	127
120	120/220	110/220	125/250	107/214	127/254(d)
120	120/208Y	114/197Y	125/217Y	111/193Y(d)	127/220Y
120	240	210	240	200	250
120	480	420	480	400	500
120	600	525	600	500	625
120	2400	2200	2450	2100	2540
120	2400/4160Y	2200/3810Y	2450/4240Y	2100/3630Y	2540/4400Y
120	4800	4400	4900	4200	5080
115(e)	6900(e)	6300	6900	6000	7200
120(e)	7200(e)				
	277/480Y (f)			254/289	440/500

NOTES: (a) Except for the first line, which indicates the usual single-phase system, the figures in the second column refer to three-phase systems.

(b) In order that other numerical designations for system voltages which are sometimes used may be interpreted in terms of the "Preferred Nominal System Voltages" values shown in Table 1, the following tabulation has been prepared showing some of the other designations. It should be emphasized that all of the different values on any one line refer to the same system as defined by its zone values in Table 1.

Preferred Nominal System Voltage	Other Designations for Identical Systems
120	110, 115 or 125
120/240	110/220 or 115/230
120/208Y	115/199Y
240	220 or 230
480	440 or 460
600	550 or 575
2400	2200, 2300 or 2500
2400/4160Y	2810 or 4000
4800	4400, 4600 or 5000
7200	6600, 6900 or 7500
4800/8320Y	8000

(c) Equipment designed for the Favorable Zone will in general give fairly satisfactory operation throughout the Tolerable Zone, except that modification of loading or alternate designs may be required for certain types of equipment.

(d) Equipment to be used on both the 120/208Y and the 240-volt systems must recognize the minimum voltage of the former and the maximum voltage of the latter.

Typical Arrangement of Power Systems

Electric power systems for hospitals must, as a minimum, include two separate sources of electricity--a normal source and an alternate source. 2(c), 4, 5/ The normal source supplies the entire hospital except when this source is interrupted. When the normal source is interrupted, the alternate source is connected to specific important circuits. In most cases, the normal source is a public utility service feeder and the alternate source is one or more generating units on the hospital site, or the alternate may consist of two sources--a second utility feeder and one or more generators on the site. (See diagrams in figs. 1 to 4, inclusive.)

On-Site Generation of Normal Power Source

In some cases, the normal power source is supplied entirely by generators on the hospital site. Systems of this type are generally referred to as total energy systems. The alternate source may then be a utility service feeder or additional generating capacity. This additional capacity may be supplied by one or more separate generators reserved for emergency use only or by one or more generators that supply the normal source. These generators must be so sized, operated, and controlled, that with one or more of them out of service because of breakdown, repairs, or routine maintenance, the remaining generators in service have the capacity and are automatically controlled for maintaining continuous service to the specified emergency and critical circuits.

Emergency Generating Unit Prime Movers Used for Other Service

Prime movers of emergency generating units are sometimes used for driving other equipment, such as air compressors, when not required to drive the generators to supply emergency electricity. Where such operation is permitted, there should be two or more of these units, each equipped with a quick-change coupling device for detaching the other equipment and reconnecting the generator. The recoupling and generator unit controls should be such that the generator is capable of delivering the emergency power demand within 10 seconds from the time normal service is interrupted. In this situation, prime movers and generators should be so sized and operated that when one prime mover is out of service because of breakdown, repairs, or routine maintenance, the remaining units are capable of supplying the specified emergency circuits within the time limit specified (10 seconds).

Design to Meet Local Needs

Codes and standards for the installation of the ordinary normal electric power systems are generally well known and routinely followed. The emergency or alternate systems for hospitals present more of a problem because of the relative newness of applicable standards and the variations permitted to meet local needs.

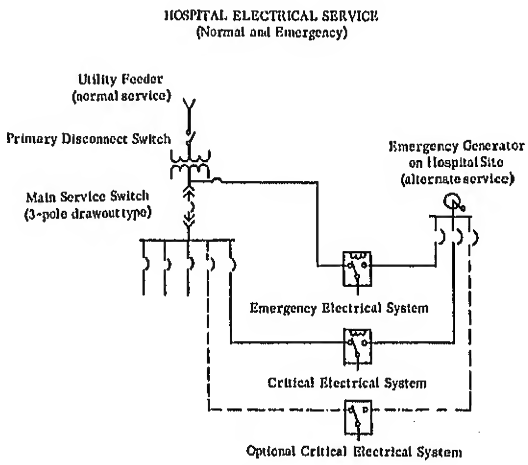

Figure 1.--Typical arrangement of main electrical service facilities for hospital supplied by one utility service feeder and one or more emergency generators, showing the generator emergency service interconnected with the utility service ahead of the main service switch. (NEC 700-8 and 10)

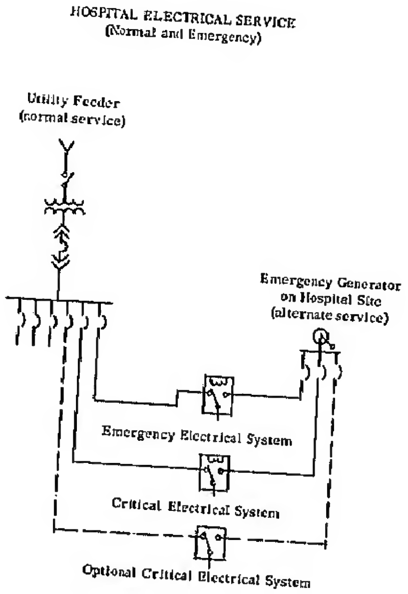

Figure 2.--Typical arrangement of main electrical service facilities for hospitals supplied by one utility service feeder and one or more emergency generators, showing the generator emergency service interconnected with the utility service at the main switchboard. (NEC 700-8)

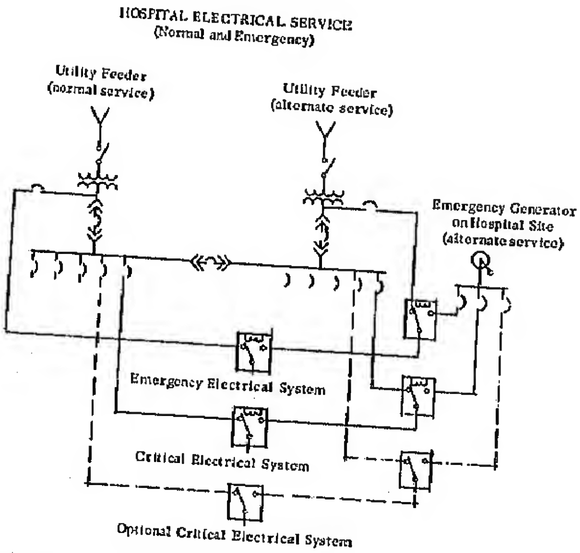

Figure 3.--Typical arrangement of main electrical service facilities for hospitals supplied by two utility service feeders and one or more emergency generators, showing the generator emergency service interconnected with the utility service ahead of the main service switch. (NEC 700-8, 9, and 10)

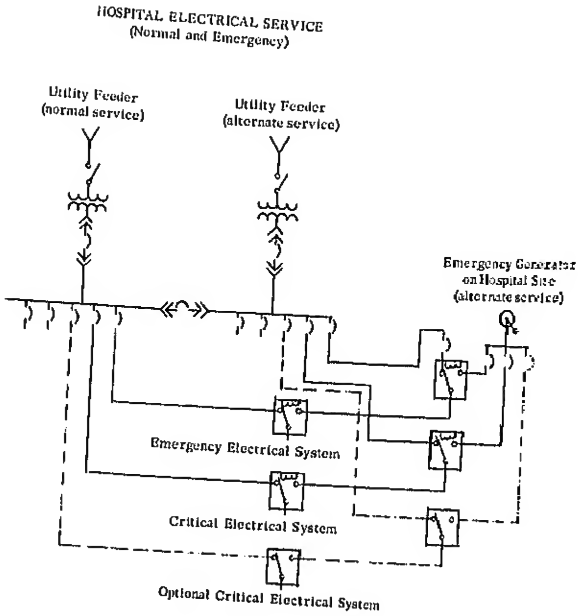

Figure 4.--Typical arrangement of main electrical service facilities for hospitals supplied by two utility service feeders and one or more emergency generators, showing the generator emergency service interconnected with the utility service at the main switchboard. (NEC 700-8 and 9)

Although applicable codes, standards, and local regulations must be met to the satisfaction of the local enforcing authority, they usually allow considerable latitude for the designer to select the combination of systems and services that meet the needs and have the greatest advantage for a particular hospital.

A competent electrical design engineer will be familiar with all codes and standards that the local inspection authority requires to be met. One or more of the following national codes, standards, regulations, and guides may apply to emergency electrical systems: The National Electrical Code (NEC), NFPA No. 70, 2(a)/ Standard for Essential Hospital Electrical Service, NFPA No. 76, 2(c)/ Public Health Service Publication No. 930-A-7, 4/ and the American Hospital Association's guidelines. 5/

NFPA No. 70 has been adopted by most States and local enforcing authorities. NFPA No. 76 has been adopted by some States and is being followed in some locations in other States. PHS Publication

No. 930-A-7 applies specifically to hospitals and health facilities constructed under the Hill-Burton program. American Hospital Association guidelines for emergency electric services are directed to member hospitals of the American Hospital Association.

Sources of Emergency Power

Because most inspection authorities require compliance with the NEC, attention is directed to sec. 700-6 of the Code with permits an option of selecting any one or more sources of emergency electricity as follows:

Section 700-7--Storage battery.
Section 700-8--Generating set.
Section 700-9--Separate utility service line
Section 700-10--Connection to the normal service feeder ahead of the main disconnecting means.

NFPA No. 76 and PHS Publication No. 930-A-7 require that a generating set be located on the hospital site. Additional sources of emergency electricity may be provided when they are available and practicable to obtain. AHA guidelines recommend essentially the same sources as NFPA No. 76 and PHS Publication No. 930-A-7. Storage batteries are useful supplements to the emergency electrical systems, but they should not be used in place of a generator or utility service feeder as the source of energy for the emergency electrical system. They can only deliver full power for a relatively short time, and their d-c current is not suitable for direct interchange with a-c current for some equipment, such as fluorescent lamps and most motorized equipment. Storage batteries are usually supplied as a part of unit equipment consisting of battery, charger and light, and a self-contained emergency lighting unit described in NEC sec. 700-22.

Typical wiring arrangements for application of these code sections, except those pertaining to storage battery units, are illustrated in figs. 1-4.

Alternate Electric Service Connections

Lighting and equipment to be energized by the alternate electric source are usually connected through two or more systems, sometimes designated as emergency and critical systems. Dividing the alternate service into separate systems allows: (1) keeping the designated emergency system small so that its reliability will be proportionately great, (2) a minimum footage of separate raceways required for emergency conductors, (3) separation of the alternate service into separate systems providing a high degree of protection against total interruption of the alternate service due to a fault within the hospital wiring system, and (4) simplicity and possible economy in providing the transfer switching of equipment.

Emergency lighting of hospital exitways has been a requirement of the Building Exits Code (now the Life Safety Code) for many years. 2(d)/ The other codes, standards, and regulations mentioned above list additional lighting requirements and specific motorized equipment, controls, communication, and alarm circuits. The aims of these codes and standards are to preserve the integrity of the emergency systems by limiting the circuits that can be connected to it and to permit the remaining needed circuit to be connected to other systems, such as the critical systems in figs. 1-4.

The needs of hospitals vary according to their program of clinical procedures. As an example, a hospital programed to do special procedures, such as open heart surgery, kidney, or other transplants, should provide for emergency operation of all lighting and equipment needed for these procedures whether or not they are listed in codes and standards.

Heating While Normal Electric Service is Interrupted

Conventional steam heating plant.--Where space heating is required and provided by the conventional steam boiler, provision should be made for emergency operation of the heating plant including motors, controls, and lighting needed for plant operation to assure safety of plant and operating personnel as well as comfort of patients. Electrically driven pumps and fans used for circulating the heat medium (liquid or air) should be connected for emergency operation.

Electric heating.--Where electricity is the sole source of power for heating, the capacity of

the on-site alternate source of electricity should be sufficient to heat all areas of the hospital plus one sterilizer except as follows: In climates where the design temperature is more than +20°F, the capacity of the alternate source for heating operating, delivery, labor, recovery, intensive care, and patient rooms and nurseries will not be required.

However, for hospitals that have an emergency generator and are also supplied by more than one utility service feeder, the generator capacity required for emergency heating of the above-listed locations may optionally be reduced by the amount required for heating patient rooms. This is because of the improvement in dependability of the utility service shown by records of interruptions of utility service to hospitals. The number and duration of simultaneous interruptions of both feeders of a double-fed hospital are considerably less than for the one feeder of single-fed hospitals.

Patients under blankets will probably not be subjected to an unreasonably low temperature when heat is not supplied to the room for periods up to about two hours. However, the decision on whether to provide the additional generator capacity in addition to a second utility feeder for heating of patient rooms is optional and should be based on local requirements or local conditions.

Fallout-Protected Hospital Emergency Service

Hospitals designed for protection against radiation fallout require a greater capacity of the alternate emergency service than ordinary hospitals because they must be equipped to care for more people for a longer time than ordinary hospitals. 6/ It is estimated that the number of nonpatients who may be admitted to the fallout-protected hospital in an emergency may be approximately 10 times the normal occupancy of patients and staff.

No-Break Electric Power

and kidney transplant are performed. Th[illegible] a number of different ways of supplying [illegible]tially no-break power. For example, one [illegible] utilizes a storage battery for instantaneou[illegible] ation of a motor-generator set to supply [illegible] during the short time required to start the [illegible] combustion engine generator set. Another [illegible] uses a direct connected generator-en[illegible] flywheel-motor assembly. During normal [illegible] by periods, when emergency power is n[illegible] quired, an electric motor rotates the [illegible] open-valved engine with heavy flywheel att[illegible] and the generator is regulated to deliver no [illegible] Interruption of normal electric supply aut[illegible]cally disconnects the electric motor, star[illegible] engine firing, and regulates generator contr[illegible] deliver full voltage to the emergency system. [illegible] the interim of changeover, the inertia of the [illegible] flywheel maintains rotation of the generating [illegible]

Generators on the hospital site may be driv[illegible] by any suitable prime mover, such as gasoli[illegible] gas, or diesel oil internal combustion engines [illegible] steam turbines. Selection of the type of gener[illegible]ting unit is usually influenced by the dependabili[illegible] of fuel supply and whether the emergency po[illegible] will be used frequently to carry a part of the l[illegible] during normal operation. Generally, the intern[illegible] combustion engine generating units are intende[illegible] for use only during interruption of the norma[illegible] power supply. Steam turbine units, in additi[illegible] emergency use, are sometimes operated da[illegible] during periods of maximum demand. Such oper[illegible]ation, if acceptable to the utility company, [illegible] result in a lower total power cost, where the pow[illegible] rate incorporates a demand charge.

Installation of combustion engines and fu[illegible] supply tanks should comply with NFPA No. 37. 2(j) Guidance in the selection of diesel engines an[illegible] associated auxiliary equipment is given in Nation[illegible] Research Council Publication No. 1132. 7/

An arrangement of internal distribution feeders so that a planned selection of loads may be connected or dropped from the emergency source is desirable to utilize more fully the available capacity of the emergency service and also to prevent overloading to the point of trip-out of the entire system. Such a design is a particularly important convenience when a fixed or mobile emergency capacity is added to the system. The transfer switching from the interrupted normal power supply to the emergency power supply for lighting exit ways, operating and delivery tables, and equipment on which human life may depend, should be automatic. Pickup or dropout of other circuits for less critical areas and functions should be selective and may be either manual or automatic. Simultaneous starting of several motors should be avoided. Manual or time-delay switching for these circuits is recommended. In some hospitals designed for treatment of poliomyelitis patients, circuit feeders may be divided into three groups designated as "critical," "semicritical," and "noncritical."

Telephone–Main Service

The procedure for planning the telephone service is similar to that for electric service. The telephone company should be consulted to discuss rates and to determine the extent, type, and arrangement of service to be supplied.

Usually it is the responsibility of the hospital to provide conduit, wire closets, and/or suitable space for installing telephone equipment. It is common practice for the telephone company to install cables and other equipment.

If the electric feeders are brought in underground, telephone cables should also be underground and should be routed to avoid locations where they would be subject to mechanical injury, excessive heat, and chemical erosion. 8/ Telephone and electric power conductors are not permitted in the same raceway, junction box, or cabinet. (See Telephones, p. 25.)

EQUIPMENT

Motors–Effect of Voltage and Frequency Variation

Polyphase induction motors are designed to operate successively: (1) when the voltage variation does not exceed 10 percent above or below normal; (2) where the frequency variation does not exceed 10 percent above or below the normal; and (3) where the sum of the voltage and frequency variation does not exceed 10 percent (provided the frequency variation does not exceed 5 percent) above or below normal. 9,10/

Where induction motors are operated at a voltage or frequency above or below their normal rating, the characteristics will vary approximately as shown in table 2.

Motor Starters–For Large Motors

Starting currents for motors normally range from 3 to 6 times the motor full-load running current. Large motors such as those sometimes used to operate large fans or compressors in connection with air-conditioning equipment, when started across the line with full voltage, may draw starting currents in excess of that allowed by the electric utility company, or they may require conductors too large to be practicable to install.

Motor starting currents can be kept within practical limits by several methods including reduced voltage and reduced torque provided by autotransformers, resistors, and switching the Wye-Delta connection. Starters for reduced motor starting current must be selected for the specific motor applications. Hence, where motors are supplied as a part of a manufacturer's assembly of mechanical equipment, it is important that the starting current limitations, if any, be made a part of the specifications and that the motor starting equipment be supplied as part of the unit equipment, or so specified to assure compatibility. It is also important that mechanical and electrical engineers consult with each other and coordinate their plans and that the electrical contractor be apprised of these electrical requirements prior to start of conduit installation or purchase of conductors.

Table 2.--GENERAL EFFECT OF VOLTAGE AND FREQUENCY VARIATION ON INDUCTION-MOTOR CHARACTERISTICS 9/

Characteristic	Alternating-current (induction) Motors			
	Voltage		Frequency	
	110%	90%	105%	95%
Torque: *				
Starting and maximum running	Increase 21%	Decrease 19%	Decrease 10%	Increase 11%
Speed: †				
Synchronous	No change	No change	Increase 5%	Decrease 5%
Full load	Increase 1%	Decrease 1.5%	Increase 5%	Decrease 5%
Percent slip	Decrease 17%	Increase 23%	Little change	Little change
Efficiency:				
Full load	Increase 0.5 to 1 point	Decrease 2 points	Slight increase	Slight decrease
3/4 load	Little change	Little change	Slight increase	Slight decrease
1/2 load	Decrease 1 to 2 points	Increase 1 to 2 points	Slight increase	Slight decrease
Power factor:				
Full load	Decrease 3 points	Increase 1 point	Slight increase	Slight decrease
3/4 load	Decrease 4 points	Increase 2 to 3 points	Slight increase	Slight decrease
1/2 load	Decrease 5 to 6 points	Increase 4 to 5 points	Slight increase	Slight decrease
Current:				
Starting	Increase 10 to 12%	Decrease 10 to 12%	Decrease 5 to 6%	Increase 5 to 6%
Full load	Decrease 7%	Increase 11%	Slight decrease	Slight increase
Temperature rise	Decrease 3 to 4°C	Increase 6 to 7°C	Slight decrease	Slight increase
Maximum overload capacity	Increase 21%	Decrease 19%	Slight decrease	Slight increase
Magnetic noise	Slight increase	Slight decrease	Slight decrease	Slight increase

* The starting and maximum running torque of a-c induction motors will vary as the square of the voltage.

† The speed of a-c induction motors will vary directly with the frequency.

Switchboards and Panelboards

All switchboards and panelboards should be of the dead-front type, enclosed in metal cabinets with hinged doors and latches, and should have the connection schedule under a transparent protective material. They should be installed in a permanently dry location unless protected by a weather-proof enclosure. Where locked cabinets are provided, all locks should be keyed alike, except the cabinets housing the emergency panels.

Switchboards and panelboards should be provided with suitable working space and maintained as required by the NEC Article 384. 2(a)/

Switchboards that have thermal trip overload devices should be located in a well-ventilated space to prevent trip-out at less than the present

current rating, which may result because of excessive ambient temperature.

Distribution panelboards for ordinary lighting and receptacle circuits should be located in corridors or in wire closets rather than in linen or janitor's closets. They should be located on the same floor as the respective lighting outlets and should be spaced so that the length of the branch circuits will not exceed approximately 100 feet.

Switches

Air circuit breakers for power and light feeders and for the lighting and receptacle branch circuits are preferred to fused switches, although the initial installation is more expensive.

Circuits of large capacities are usually interrupted by either oil- or air-type automatic circuit breakers. Although oil breakers are highly dependable and are required under certain conditions, air breakers (where applicable) are preferred to oil breakers in hospitals because they conserve space and eliminate the need for maintaining oil-bearing switching equipment.

Silent-type wall switches for control of lighting circuits are recommended in all patient areas to reduce noise. Wall-mounted switches are preferred to pull switches to reduce maintenance. Where lights are installed in small closets, door-operated switches are recommended. Switches installed or operated within a location defined as hazardous because of storage or use of flammable anesthetic agents should be approved for use in Class 1, Group C hazardous atmospheres (explosionproof). Switches controlling the ungrounded circuits in anesthetizing locations such as operating and delivery rooms must have a disconnecting pole in each conductor. For these locations, two-pole switches are required for single-phase lighting and receptacle circuits.

A low-voltage system of switching lighting circuits is applicable in hospitals, particularly in large areas such as auditoriums, dining areas, laboratories, and for lighting that is on grounded circuits in anesthetizing locations.

Dimmers of various types are available for control of light intensity for incandescent and fluorescent lamps. For dimming incandescent lamps, on an alternating current system, three general types are applicable:

1. Adjustable rheostat in series with the lamps. This method of dimming offers no saving in power when the illumination is decreased, because the power saved in the lamp-lighting output is approximately equal to the power consumed as heat in the dimmer.

2. Autotransformer for varying the voltage in the lamp supply circuit. This method does permit a saving in power since there is no appreciable loss in the dimmer when the lights are dimmed.

3. Silicon controller rectifier (SCR) assembly. These devices are available for dimming from 100 percent light output to blackout, sized to fit into an ordinary switch box for a typical 500-watt capacity. Other assemblies of SCR are arranged as a dimming switch with three positions: 100 percent light, 30 percent light, and "off."

Both the adjustable rheostat (resistor type) and the autotransformer type of dimmers are applicable to large and small incandescent lighting systems and permit dimming over the entire range of lighting intensity. These dimmers described for incandescent lamps are not suitable for dimming fluorescent lamps.

A number of arrangements are available for dimming fluorescent lamps, including the use of autotransformers and SCR devices.

Wire

All feeder and branch circuit conductors should have high-grade insulation to assure optimum life and dependability of the electrical system. High-temperature wire is required at such places as range hoods and boilers. Lead sheath or waterproof wire should be used underground and where condensation may form, as in outdoor conduits, refrigerator boxes, roof slabs, and connections to outside lights. The NEC code should be consulted for special conditions.

Prices and the short supply of copper have resulted in the exploitation of aluminum conductors and the development of aluminum wire

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connectors and tools for installation of aluminum conductors and for joining aluminum conductors to copper conductors. The size of aluminum conductors is generally limited to No. 6 and larger because of the difficulty in making and maintaining terminal connection at devices with smaller size conductors. 11,12/

Conduit and Fittings

All hospital wiring should be in conduit to facilitate alterations and repairs. Wiring for the patient-nurse call system should be in conduit of ample size to permit a reasonable amount of change in the system with a minimum amount of labor and alteration to building structure.

Where only one set of service conductors is brought into the building underground, spare conduit facilities that permit installation of other conductors should be provided to expedite restoration of service in case of a failure in the supply lines between the building and the street or point of main connection.

Underground conduit should be nonmetallic and encased in concrete. Rigid metal conduit, properly sealed, is required for explosionproof wiring (see NEC Article 517). 2(a)/ Spare conduit or sleeves through walls or floors are advisable where future service is planned or contemplated.

Metal conduit installed outdoors, above ground, and exposed to natural changes in temperature and atmospheric conditions, usually breathes and collects an appreciable amount of water inside the conduit. Unless such conduit is positively sealed, weep holes of about 1/4 inch diameter should be provided in the lowest portion of the conduit for drainage of this condensate.

Aluminum conduit may be considered for installation of No. 2/0 and larger conductors inside the building, as a possible saving in cost. 13/ Aluminum conduit should not be used where it is to be embedded or partially embedded, in concrete. 14/

Boxes for housing switches, receptacles, or other devices should not be mounted back-to-back in partitions between occupied spaces unless they are suitably sound-insulated.

Receptacles (Convenience Outlets)

Receptacles should be installed in all places where plug-in service is likely to be required. They should be mounted at a height convenient for use and located, or horizontally spaced, to minimize the need for alterations or extensions of service after the hospital is completed. It is common practice to install duplex receptacles throughout the hospital except where heavy duty or other specific services are required, such as in anesthetizing locations, for portable X-ray, and for heavy-duty service equipment. Grounding type receptacles are required in all locations (see NEC sec. 410-55). 2(a)/

Receptacles in anesthetizing locations should be of the type described in NFPA No. 56, secs. 2438 and A2438. Receptacles in these locations for general purpose use should be the lock-in type rated at 20 amperes, 125 volts a-c, 2-wire, 3-pole. Other receptacles of a different current or voltage rating may be installed in anesthetizing areas for special equipment such as portable X-ray or electronic devices. These should also be the type described in sec. 2438 of NFPA No. 56. The 200 ma and 300 ma explosionproof mobile X-ray units require 60 amperes, 600 volt a-c (250 d-c), 2-wire, 3-pole receptacles. To gain advantage of minimum size, weight, and capacitance relating to leakage current, these receptacles for mobile X-ray units may be nonexplosionproof if located more than 5 feet above the floor. For improved appearance, they may be flush mounted in a metal box with hinged cover. Where the same X-ray unit is used both in anesthetizing locations and in nursing areas, all receptacles for X-ray use should be the same type so that the plug on the mobile unit will fit all of these receptacles, even though receptacles in one location are explosionproof and in the other location, nonexplosionproof. The same provision applies to heated bassinets that may be plugged into outlets in delivery rooms and in nurseries.

Patients' bedrooms should have at least 3 duplex receptacles for single-bed rooms with two outlets near the head of the bed. Multibed rooms should have a similar arrangement of receptacles. Preferably, there should be two duplex receptacles at the head of each bed, in addition to any required for motorized beds. Where use of motorized beds are planned, one 20-ampere receptacle should be

located on the wall back of the bed headboard about 12 inches above the floor. The 2 additional receptacles on the head wall at each bed should be located one on each side of the bed for versatile use about 3 feet above the floor to minimize stooping. These receptacles for appliances should be located where they are convenient to reach and not near the floor, or behind beds or furniture.

Nurseries for infants should have one duplex receptacle for each ordinary bassinet in each cubicle and at observation or examination stations. Where heated bassinets are connected in delivery rooms and also in nurseries, receptacles in nurseries should be of the type installed in delivery rooms.

Corridors should have receptacles rated at 20 amperes or more, as required for floor cleaning machines and for other general uses. These receptacles in corridors of patient areas should be spaced about 40 feet apart, or within convenient reach from each bedroom, and preferably along each side of the corridor to minimize traffic over extension cords when portable equipment is plugged in. Other receptacles similarly installed but specifically for use of mobile X-ray should be located in corridors of nursing areas.

Intensive care nursing units should have, as a minimum, receptacles as follows: two 20-ampere, 125-volt, single-phase, duplex receptacles at the head of each bed and at the nurses' station for routine use; one 30-ampere, 230-volt, single-phase, single receptacle in each room (multiple or single-bed room) for possible use of heavy-duty equipment such as an artificial kidney. Outlets or conduit provision for later installation of wiring for electronic monitoring equipment should be installed for connection between the head wall at each bed and a central monitoring station. One or more receptacles for use of mobile X-ray should be installed and located so that it is within easy reach of any patient bed within the intensive care unit.

Recovery rooms should have the same outlet and conduit arrangement as intensive care nursing units.

Clocks

An electric clock system rather than individual clocks should be provided, with clocks in all offices, nurses' stations, main lobby, waiting rooms, telephone switchboard, kitchen, dining room, laundry, boiler room, shops, laboratories, central supply areas, emergency rooms, operating rooms, and delivery rooms. Clocks with narrow frames and boldface Arabic numerals are preferred. Clocks in operating and delivery rooms should have sweep second hands. The need for elapsed time indicators in all operating and delivery rooms is controversial. However, they are installed in many hospitals. Where they are provided, elapsed time indicators should indicate seconds, minutes, and hours. Maximum indication of only 60 minutes is usually insufficient because many operations greatly exceed 60 minutes.

Two types of clock systems are available--the wired and the electronic. The wired system requires wiring from the individual clocks to the master control clock. The electronic system requires no control wiring connection between the individual clocks and the master clock. Electronic clocks may be operated from any convenient outlet on the electric system, but they are controlled by means of electrical impulses sent out by the master control clock and picked up by a radio-type receiver in each clock.

Consideration of the relative costs of these two clock systems, based on new building construction, indicates that the total installed cost of the electronic clock system would usually exceed that for the wired clock system. However, for installation in an existing building or expansion of an existing system, the electronic clock system would usually cost less than the wired system.

Anesthetizing Locations

Anesthetizing locations are rooms in which any of the anesthetic agents are administered to a patient in the course of examination or treatment. An anesthetizing location may or may not be classified as a hazardous location, depending on whether or not flammable anesthetic agents are used in the area.

Hazardous Locations

A hazardous location in a hospital is defined as a space where there is a potential danger of

explosion because of the presence of volatile flammable anesthetic or disinfecting agents. Anesthetic storage rooms are considered hazardous throughout.

The hazardous location of an anesthetizing room is considered to include the entire floor area of the room, to a height of 5 feet above the floor. All hazardous locations require special precautions for their construction, equipment, and operation to prevent ignition of those agents which cause fires and explosion. All equipment used in these areas should be approved for use in Class 1, Group C hazardous atmospheres. For specific requirements, see NFPA No. 56. 2(b)/

All hazardous locations within surgical and obstetrical suites require conductive floors. The electrical resistance of these floors should be only moderately conductive to serve two electrical functions: (1) to provide a conductive path for neutralizing static charges to prevent electrostatic sparks and possible ignition; (2) to act as a resistor to limit current through it from the electrical system in case of a short or insulation fault, so as to minimize electric shock or ignition from arcs or sparks from the fault. 15/

Operating and delivery rooms require ungrounded electrical distribution systems for all wiring as an additional safeguard against the hazards of electric shock and the ignition of flammable anesthetic agents by sparks from the electric system, except that ordinary grounded systems may be connected to: (1) fixed nonadjustable lighting fixtures located more than 8 feet above the floor, and (2) permanently installed X-ray tube head and cables that are approved for use in Class 1, Group C locations. (See NFPA No. 56, sec. 2444 and 2446.) 2(b)/

As a safety precaution against electric shock, the leakage current from an ungrounded system is specified not to exceed 2 milliamperes. 2(b)/ To avoid disapproval by the inspection authority after the system has been installed, the system design should be carefully evaluated and designed to meet code requirements before construction is started. The current leakage for the system may be estimated separately for the following:

1. Total conductors of ungrounded system.

2. Equipment, maximum connected at one time.

3. The isolation transformer.

4. The ground detector unit.

Leakage for the system is the sum of 1 to 4, inclusive. The approximate leakage current values for 2, 3, and 4 can usually be obtained from the manufacturers. Leakage current for 1 (conductors) must be calculated for each specific job to account for the various lengths of conductors shown on the plans. Formulas for calculating conductor leakages are available in electrical engineer handbooks. (Also, see refs. 14, 16, and 17.)

A ground detector system is required to warn of accidental or faulty ground on the ungrounded system. The detector system and its operation are described in NFPA No. 56, 2(b)/ and in other publications. 18, 19/ It is recommended that the ground detector be the dynamic type, capable of continuous monitoring of the electric system to detect all combinations of capacitive and/or reactive faults.

The requirement for wiring and equipment installed above the hazardous location (more than 5 feet above the floor) is the same as that for ordinary locations except that equipment should be enclosed or guarded to prevent sparks or hot particles from falling into the hazardous location.

Furniture and mobile equipment should be conductive and in electrical contact with the conductive floor.

High humidity reacts with ordinary materials in such a way that it lowers their electrical resistance or reacts with surface substances or impurities to form a conductor. Hence, controlled humidity of at least 50 percent is considered an important factor in the control of static electricity.

Lighting

Lighting in all areas of the hospital should be designed for comfortable seeing and to comply with current recommendations. 20/ High brightnesses of light sources and reflecting surfaces that

produce discomfort glare should be avoided. [21] Luminaires should be durable, standard type, neat, appropriate for the space, and easily cleaned and relamped.

Work spaces should be relatively free from shadows and have sufficient illumination on work areas to eliminate the need for portable units with extension cords on floors or on work areas.

The lighting of offices, corridors, assembly halls, shops, boiler and machine rooms, kitchens, and storage spaces can be treated as in other types of buildings. The IES Report CP-29 [20] and Handbook [22] contain information on hospital lighting. (See also tables 3 and 4 in this report.)

For patient rooms, lighting should be provided for three distinct services: general illumination for the room, a reading light for each patient, and a nightlight for the room. A fourth service, a doctor's examining light, may be a separate unit installed for examination purposes only, or a feature incorporated into the patient's reading light, or it may be supplied by a portable lamp with an extension cord. This examining light should produce approximately 100 fc (footcandles) over a limited area, but preferably over the entire bed area. A fixed, ceiling-mounted examining light arranged to illuminate the entire bed area is preferable to a portable or hand-held spotlight. Because the ceiling-mounted examining lights described may be uncomfortably glaring for the patient being examined as well as the other patients in the room, these lights should not be used longer than required for the examination.

The source of the nightlight for the room should be located so that it is out of direct sight of patients' in-bed normal position, and should be controlled by a switch at the entrance door. The recommended installation arrangement for this light is flush-mounted on the wall near the entrance doorway centered about 14 inches above the floor. Other nightlights are frequently included as an extra feature of the patient's reading light for use at the individual beds. These nightlights, switched at the bedside, permit the patient or the nurse to control these lights as needed.

Surgical recovery rooms and intensive care rooms should have about 30 fc of general illumination and a convenient means of providing about 100 fc of local lighting. Fixed units for supplying the local lighting are preferable to portable units.

A frequent complaint from patients concerning the reading light is the radiated heat from the nearby unit. A unit with an output intensity sufficient to permit adequate lighting when the unit is located a greater distance from the patient will reduce the objectionable radiant heat at the patient's head. Where two or more beds are located in one room, the reading lights should be of a type that can be installed or adjusted so as not to shine in the other patients' eyes. Each reading light should have a switch control accessible to the patient.

Operating and delivery rooms should have general illumination of at least 100 fc for the room area and special, separately controlled lights for the tables.

The major operating room light should provide a multicrossbeam originating from widely separated sources or areas, focused at the surgical field to minimize shadows and to illuminate deep cavities. This light should be capable of providing a lighting level of not less than 2,500 fc in the center of a 10-inch diameter circular area on the operating table, and not less than 500 fc at the edge of that circle, when the cover glass of the luminaire is not less than 42 inches above the surface of the table. More than one unit may be used when higher lighting levels are required. A variable control dimmer or other means of controlling the lighting level at the table is recommended.

Delivery rooms require about the same general illumination as operating rooms. If the room is used for all deliveries, including cesarean section, lighting at the table should be equal to that recommended for operating rooms. If it is contemplated that the room will be used only for normal deliveries and for those cases which require only minor surgery, the light at the table may range from 1,000 to 2,000 fc.

Minor surgery, emergency rooms, cystoscopic rooms, and autopsy rooms should have about 100 fc for general illumination. These rooms should have supplemental lighting, either by ceiling-mounted adjustable luminaires or portable units that provide spot intensities up to 2,500 fc over a circular area of at least 8 inches in diameter.

Fracture rooms need about 50 fc for general illumination with about 200 fc supplemental lighting for the table.

An X-ray film illuminator is required in each operating room. It is also desirable that one be installed in the doctors' locker room of the obstetrical suite.

Where critical observation of skin, tissue, or specimen involves color definition as in surgery, laboratories, and autopsy rooms, the light should provide a color rendering effect that permits optimum judgment in evaluating the true conditions. A color rendering index of at least 85 is recommended. (See fig. 5-17 of ref. 22.)

Some fluorescent lamps produce lighting that accentuates certain colors and are deficient in others, to the extent that the color of skin, biological samples, and some food products appear unnatural. Such lamps should not be installed in patient areas or dining areas. Daylight color quality of lighting is preferable for critical judgment in color matching or color definition. Because there is some variation in the color quality of daylight produced by direct sunlight, north sky, and overcast sky, a more exact definition of daylight color is needed as a standard for comparison. In this instance, it is recommended that standard source C, adopted by USASI, 23/ be the reference lighting color provided by a combination of direct sunlight and clear sky, having a correlated color temperature of approximately 6,770°K. A practical and close approach to 6,770°K may be provided by a lighting unit combining specially made fluorescent and incandescent lamps and glass diffuser. However, for ordinary laboratory, noncritical seeing tasks, cool white (improved color) fluorescent lamps provide fairly satisfactory color rendition.

The preferred lighting in dental laboratories for denture matching is daylight, or the 6,770°K standard described.

The lighting in nurseries for care of newborn infants should be of a color quality optimum for visual early detection of jaundice and cyanosis. Since daylight accentuates all colors, it permits visual discrimination of the colors which indicate the difference between health and disease of babies. In the absence of daylight or availability of standard source C, combinations of available light sources such as the following may be used to obtain a reasonable approach to the energy distribution in the spectral range of the colors produced by jaundice and cyanosis: For visual detection of jaundice, an equal number of natural or warm white and cool white (improved color) fluorescent lamps; for detection of cyanosis, daylight fluorescent lamps. Where the same lighting is to be used for visual detection of both jaundice and cyanosis, an equal number of daylight and natural or soft white fluorescent lamps produces fairly satisfactory lighting. Another approach to satisfactory lighting of infant nurseries is to provide a light source with correlated color temperature of at least 4,000°K (6,770°K preferred) and a color rendering index of at least 83 percent.

For general lighting in the operating and delivery rooms, the direct and indirect costs of maintaining and operating a fluorescent lighting system afford significant advantages over a system using incandescent filament lamps. The lumen output per watt of fluorescent lamps is about 2 1/2 to 3 1/2 times that of incandescent lamps, varying according to the lamp wattage rating and light color type of the fluorescent lamps. Relating this to the heat produced by the two types of lighting, as it affects air conditioning, an incandescent lighting system will produce about 2 1/2 to 3 1/2 times the amount of heat produced by a fluorescent lighting system of equal footcandles.

Illuminated signs may be required in areas where there is much visitor traffic, such as at the information desk, cashier's office, and outpatient department. Where such lighting is likely to be provided by portable units, outlets or plug-in receptacles should be located for convenient use.

Tables 3 and 4 give lighting levels recommended for hospitals, based on reports of the Illuminating Engineering Society. Table 3 lists the recommended lighting levels for normal service. Table 4 lists reduced lighting levels, the least that should be maintained while the normal source of power is interrupted and lighting is being supplied by an emergency electrical source.

Table 5 gives lighting levels recommended for nursing homes. Older patients in nursing homes need better lighting than do the normally younger patients in general hospitals.

Table 3.--LIGHTING LEVELS RECOMMENDED FOR HOSPITALS

Area	Footcandles*
Anesthetizing and preparation room	30
Auditorium	
Assembly	15
Exhibition	30
Social activities	5
Autopsy and morgue	
Autopsy room	100
Autopsy table	1000
Museum	50
Morgue, general	20
Central supply	
General, workroom	50
Needle sharpening	150
Syringe room area	150
Worktable	70
Inspection for tears and defects	100
Glove room	50
Storage area	30
Issuing sterile supplies	70
Corridor	
General-nursing areas (daytime)	20
General-nursing areas (nighttime)	3
Operating and delivery suites	30
Laboratories	20
Cystoscopic room	
General	100
Cystoscopic table	2500
Dental suite	
Waiting room	
General	20
Reading	30
Operatory, general	100
Instrument cabinet	150
Dental chair, at patient's mouth	1000
Prosthetic laboratory, bench	300
Recovery room, for patient's rest	5
Recovery room, for observation	70
Dietary facilities	
Food production, general	50
Preparation and cooking	70
Patient tray, assembly	50
Cafeteria	
Counter display	70
Serving	70
Cashier	50
Dining	30
Dietary facilities (con.)	
Cleanup	
Dishwashing	70
Potwashing	50
Canwashing	30
Cartwashing	30
Storage	
Refrigerated, dry and day	50
Central, food	50
Trash	30
Office, dietitian	100
Janitor's closet	30
EKG, BMR, and specimen room	
General	30
Specimen table (supplementary)	50
EKG machine	50
Electromyographic suite	
General	30
Preparation for examination	50
Examination (reduce to local)	1
Elevators	20
Emergency operating room	
General	100
Local	2000
Encephalographic suite	
Office (see offices)	
Workroom, general	30
Workroom, desk or table	100
Patient preparation room, general	30
Patient preparation room, local	50
Patient examining room, general	70
Storage, records, charts	30
Examination and treatment room	
General	70
Examining table	200
Exits, at floor	1
Exit signs, on face of sign	5
Eye, ear, nose, and throat suite	
Darkroom, variable	0-10
Eye examination and treatment room	50
Ear, nose, and throat room	50
Flower room	10
Formula room	
Bottle washing	30
Preparation and filling	50

*Minimum on task at any time.

Table 3.--LIGHTING LEVELS RECOMMENDED FOR HOSPITALS (Con.)

Area	Footcandles*
Formula room (con.)	
Liquid inspection	100
Fracture room	
General	50
Fracture table	200
Splint closet	50
Plaster sink	50
Intensive care nursing areas	
General	30
Local	100
Laboratories	
Assay rooms, general	50
Worktables	70
Close work and microslides	300
Laundries	
Sorting and washing areas	50
Flatwork ironing	50
Machine pressing	70
Fine hand ironing	100
Sewing room	100
Libraries	
Reading room	
Study and notes	70
Ordinary reading	30
Stacks	30
Cataloging	50
Card files	70
Check-in-and-out desk	70
Linens	
Sorting soiled linens	30
Central clean linen room	30
Loading carts (or issuing)	50
Linen closet	10
Locker rooms	30
Lobby	
Day	50
Night	20
Lounge rooms	
General	10
Reading	30
Maintenance shop	
General	30
Bench work (rough)	50
Bench work (medium)	100
Bench work (fine)	500
Painting	50
Maintenance shop (con.)	
Paint storage	10
Testing, general	50
Testing, extra fine instruments	200
Materials handling	
Load and unload platforms	20
Picking stock, classifying	30
Wrap, pack, and label	50
Medical records room	100
Nurses' station	
General (day)	70
General (night)	30
Table, doctors make and review reports	70
Desk and charts	70
Medication room counter	100
Nurses' gown room	
General	30
At mirror	50
Nurses' workroom	50
Nurseries, infant	
General	30
Treatment room	100
Examination table	200
Local, at infant bassinet	100
Obstetrical	
Cleanup room	30
Scrubup area	30
Labor room, general	20
Labor room, local	100
Delivery room, general	100
Delivery table	2500
Substerilizing room	30
Recovery room, general	30
Recovery room, local	100
Offices	
Bookkeeping and fine work	150
Reading and transcribing good quality paper	70
Intermittent reading, conference, etc.	30
Information and telephone switchboard	30
Parking lot	1
Patient room (private and wards)	
General	10
Reading	30

*Minimum on task at any time.

Table 3.--LIGHTING LEVELS RECOMMENDED FOR HOSPITALS (Con.)

Area	Footcandles*
Patient room (private and wards) (con.)	
Observation by nurse	2
Psychiatric, disturbed patients	10
Nightlight at floor (variable)	0.5 to 1.5
Examining light	100
Mirror at lavatory	50
Toilet	30
Pediatric nursing unit	
Cribroom, general	20
Bedroom, general	10
Reading	30
Dayroom or playroom	30
Treatment room, general	50
Treatment room, local	100
Pharmacy	
General	30
Worktable, compound and dispense	100
Parenteral solution room	50
Active storage	30
Alcohol vault	10
Power, central station	
Boiler room, general	10
Burner platform	20
Water treating area	20
Generator and switchboard room	20
Rear of freestanding switchboard	10
Emergency generator room	20
Private rooms, interns	
General	10
Reading	70
Radioisotope facilities	
Radiochemical laboratory	50
Uptake measuring room	30
Examination table	200
Retiring room	
General	10
Reading, local	30
Solariums	
General	20
Reading	30
Stairways	20
Storage, Inactive	5
Rough, bulky	10
Medium	20
Fine	50
Surgical suite	
Scrub-up area	30

Area	Footcandles*
Surgical suite (con.)	
Anesthesia induction room	30
Operating room, general	100
Operating table	2500
Monitoring equipment room	50
Substerilizing room	30
Storage, anesthetic agents	20
Storage, sterile supplies	30
Storage, nonsterile	30
Instrument cleanup and workroom	100
Nurses' lounge, locker, and toilet	30
Doctors' lounge, locker, and toilet	30
Postanesthesia room	
General	30
Local	100
Utility	70
Offices, supervisor, and anesthetists	70
Telephone equipment room, general	20
Switchboard	50
Therapy, physical	
General	20
Exercise room	30
Occupational therapy, general	100
Treatment cubicles, local	30
Whirlpool	20
Lip reading	150
Worktables or benches, ordinary	100
Worktables, fine work	150
Toilets and washrooms	30
Waiting room	
General	20
Reading	30
Workrooms, clean and soiled	
General	70
Work counter	100
X-ray room and facilities	
Reception and waiting	20
Radiographic, general	10
Fluoroscopic, general (variable)	0 to 10
Deep and superficial therapy	10
Control room	10
Darkroom	10
Lightroom, film viewing	30
Storage, undeveloped films	30
Storage, developed films	30
Dressing room	10
Radiologist's office	70

*Minimum on task at any time.

Table 4.--EMERGENCY LIGHTING LEVELS RECOMMENDED FOR HOSPITALS

Area	Footcandles*
Exit ways	
Corridors leading to exits, at floor	1
Stairways leading to exits, at floor	3
Exit direction signs on face of luminaire (see reference 2(d) and local codes)	5
Exit doorway, at floor	3
Operating room, surgical table	2500
Operating room, emergency table	2000
Delivery room, obstetrical table	2500
Recovery rooms for OR & OB	10
Nurseries, infant, 30 inches above floor	10
Nurseries, premature, 30 inches above floor	10
Nurseries, pediatric, 30 inches above floor	2
Medication preparation area, local	30
Nurses' station	5
Pharmacies	5
Blood bank area	5
Central suction pump area	5
Telephone switchboard, face of board	30
Central sterile supply, issuing area	5
Psychiatric patient bed area	2
Main electrical control center	5
Boiler room, general	3
Laboratories	3
Dietary, production areas	3

* Minimum on task while normal electrical service is interrupted.

X-Ray

The voltage supplied to the X-ray unit should be nearly constant so that images and pictures will be uniform and consistently reproducible. An independent feeder with capacity sufficient to prevent a voltage drop greater than 3 percent is recommended. 24/ Although 3 percent regulation conforms with recommendations of the National Electrical Manufacturers Association, some manufacturers recommend a line voltage regulation of not more than 2 percent while others are satisfied with a line voltage regulation as great as 5 percent. A separate transformer for the X-ray feeder is desirable in all cases, and it is a requirement in most cases. The voltage and number of phases of the X-ray feeder must meet the requirement for the particular X-ray unit supplied. The X-ray feeder is usually single-phase 120 volt or 240 volt, but it may be 3-phase and in some cases 480 volt. Radiation protection should be provided as recommended in applicable handbooks. 1(e), (g), (k)/

Radioisotopes

Teletherapy utilizing cobalt-60 and cesium-137, which produce gamma radiations of 1.33 and 0.661 million electron volts and have half-lives of 5.3 and 33 years, respectively, is used in place of X-ray therapy for many conditions. The radiations produced by cobalt-60 and cesium-137 are equivalent in effectiveness to approximately 2-million-volt and 1-million-volt X-ray, respectively, and require considerable radiation protection. [See refs. 1(b), (c), (d), (f), (g), (h), (i), (j), (l), and (n).]

Table 5.--LIGHTING LEVELS RECOMMENDED FOR NURSING HOMES

Area	Footcandles*
Corridors and interior ramps	20
Stairways other than exits	30
Exit stairways and landings	5 on floor
Doorways	10
Administrative and lobby areas, day	50
Administrative and lobby areas, night	20
Chapel or quiet area	30
Physical therapy	20
Occupational therapy	30
Worktable, course work	100
Worktable, fine work	200
Recreation area	50
Dining area	30
Patient care unit (or room), general	10
Patient care room, reading	30
Nurses' station, general, day	50
Nurses' station, general, night	20
Nurses' desk, for charts and records	70
Nurses' medicine cabinet	100
Utility room, general	20
Utility room, work counter	50
Pharmacy area, general	30
Pharmacy, compounding and dispensing area	100
Janitor's closet	15
Toilet and bathing facilities	30
Barber and beautician areas	50

* Minimum on task at any time.

The electric power capacity required for normal operation of these teletherapy units is relatively small. It is used to operate the light beam localizer and distance finder for positioning the patient, to open and close the source housing shutter, to operate the collimator, for vertical and rotational movement of the treatment head assembly, for the timing control, and for door interlocks.

Radioisotopes of short half-life, administered to patients orally or by injection, are usually shipped and stored in adequately shielded containers. So long as these radioisotopes remain inside these shielded containers which provide the recommended radiation protection, and so long as they are stored in small quantities, structural shielding for the building may not be necessary. When the radioactive material is removed from its shipping container, the recommended protection may be provided by lead bricks stacked or arranged to provide the necessary shielding.

Specific rules on radiation protection applying to both patient and hospital staff, after radioactive material has been administered, are given in Handbook of Rules for Administration of Radioactive Materials to Patients. 25/

Some of the radioisotopes may not be acquired, transferred, or used except as authorized by the Atomic Energy Commission or State regulatory agency. Shielding methods for protection against gamma radiation are the same as those for X-ray. (See applicable handbooks listed in ref. 1.)

Radiation Protection

Radiation protection guides have been established on the premise that everybody receives small amounts of radiation from natural sources, including cosmic radiation; that although the effects of small additional amounts of radiation are not presently determinable and may not be readily detectable, the effects, genetic or other, of any amount of radiation are believed to be greater than zero, and that radiation exposure from whatever source should be kept as low as practicable. 1(f), 26, 27/ All medical X-ray and gamma-ray exposure should be held to the minimum compatible with practical clinical requirements.

For diagnostic procedures, as well as for therapy, consideration should be given to utilizing all available means of minimizing radiation exposure to patients. Probably the most important means of limiting radiation exposure would be the use of variable aperture collimators to limit the primary radiation to only the small area of the body that is of clinical interest. Any other practicable means of reducing radiation exposure, such as using image intensifiers to compensate for a corresponding reduction in radiation, should be considered significant.

Where either teletherapy units containing a gamma-ray source, such as cobalt-60 and cesium-137, or X-ray units are to be installed, protective shielding must be incorporated into the building structure. This shielding should be carefully checked by a qualified expert at the design stage and after the units have been completely installed. In every case, evaluation should be made for primary barriers between the X-ray tube or gamma source and the occupied areas in all directions to which the useful beam may be directed and also for secondary barriers for any remaining occupied areas.

In determining secondary barriers, consideration must be given to direct or leakage radiation that passes through the protective housing around the X-ray tube or the gamma-ray emitter and also to secondary or scattered radiation that is emitted from objects being irradiated from either the useful beam, leakage radiation, or other scattered radiation.

Precipitation

Particle precipitation equipment is used to remove dust, smoke, or other particulate matter from the atmosphere in ventilating systems and to abate smoke from the boiler plant. The principle involved in this precipitation process is ionization in the air stream by high voltage-rectified current collection of the dust particles on oppositely charged surfaces, and then removal of the particles by a method that will prevent reentrainment of the collected dust particles. 28/

Dust and smoke collecting precipitators for cleaning boiler stack discharge usually employ high voltage, 30 to 100 kv, at negative polarity corona for ionization. In air cleaning for ventilating systems, a lower voltage of about 13,000 volts is generally used to produce positive corona because of its possibly lower ozone genèration. The electrically charged particles are then precipitated at about 6,000 volts direct current. Reentrainment of dust particles may be caused by dislodgement during maintenance procedures or excessive buildup due to lack of maintenance procedures or by interruption of electric service. Therefore, high grade filters are usually preferred to precipitators for ventilating systems in critical areas, such as in operating and delivery rooms.

Elevators

Since elevators affect safety and the functional efficiency of the hospital, they should be manufactured, inspected, and maintained in strict accordance with the code. 3(a), (b)/

Elevators are recognized as a specialty product. Their proper and efficient function requires routine maintenance and inspections by skilled elevator mechanics with special training and experience in this field. This is normally beyond the capabilities of personnel performing routine hospital maintenance and services. This elevator inspection and maintenance service is usually contracted for from the elevator manufacturer or his authorized agent. Therefore, it is important that elevators be purchased from a manufacturer who can show that they maintain adequate service

facilities including the spare parts necessary to ensure efficient maintenance performance and prompt 24-hour emergency call-back service reasonably close to the hospital.

There are two general types of elevator traffic which must be served in a hospital: (1) passenger traffic including doctors, nurses, technicians, general workers, and visitors; and (2) vehicular traffic including stretchers, beds, wheelchairs, portable machines, food carts, and accompanying personnel. Both types of traffic are important to the proper functioning of a hospital and both must be provided with adequate elevator service.

In most hospitals in past years, elevators have been installed having a car size to accommodate stretcher beds, and the elevators were used to carry both passengers, beds, and wheel equipment. Separate elevators for passengers and for hospital service are desirable. However, this separation may not be practical for small hospitals. For the larger hospitals, it has become the recommended practice to provide both passenger and service elevators and separate lobbies for each. Where the hospital design and size permit, this separation is considered a desirable arrangement for providing efficient elevator service for both passenger and wheeled traffic. This permits the use of wider cars with center opening type doors for the passenger traffic, expediting loading and unloading.

Elevators used for transporting patients on stretchers or beds, or for other wheeled equipment, should be of a size to conveniently accommodate the largest of such equipment contemplated. Although Public Health Service General Standards of Construction 4/ permit use of 3,500-pound elevators with car inside dimension of 5'0" by 7'6", larger elevators are generally recommended for new hospitals. All elevators should be equipped with automatic leveling devices. Tables 6 and 7 show the relative sizes of elevators, beds, and stretchers.

It is desirable that the electric service and switching facilities for elevators be arranged to permit operation of any elevator from the emergency or alternate source of electric service in case of interruption of the normal electrical service. To minimize the power demand by the elevators during an emergency, not more than one elevator should be connected to the emergency electric source at one time. Such an arrangement will permit emergency operation of any elevator that may have stopped automatically between landings when the normal electric service is interrupted.

Dumbwaiters

Dumbwaiters are available in the various sizes and capacities required for transporting materials and equipment. A popular size dumbwaiter frequently selected for hospitals has 100-pound capacity with car platform 24 by 24 inches and car height of 30 to 36 inches. However, dumbwaiter capacities and car sizes may be varied to meet specific needs within limits not to exceed 500 pounds capacity, 9 square feet of floor space, and 4 feet in height inside dimensions. Small cars of special size have been used, such as 3 by 5 inches for transporting patient records of X-ray plates and 12 by 12 inches for small trays, medicines, or surgical instruments. The large dumbwaiters are used to transport such bulky equipment as food trucks and laundry trucks.

Equipment for automatic loading and unloading of dumbwaiters is particularly useful for expediting handling of food carts and supply containers.

COMMUNICATION SYSTEMS

General

During the past 20 years, methods of communication in hospitals have changed considerably. Loud speakers, chimes, and coded bell tapes throughout the hospital, particularly in the nursing areas, for transmitting messages and locating people, are rapidly being replaced by radio. The numerous systems of intercommunicating (squawk-box) systems supplied a few years ago for transmitting interdepartmental messages have been minimized, and in some instances,

Table 6.--ELEVATORS FOR HOSPITAL USE

ELEVATOR		DOORS		CAR PLATFORM DIMENSIONS			
				Door on One End		Door on Two Ends	
Capacity lbs.	Use Practice	Type	Width Opening	Outside WXFB	Inside WXFB	Outside WXFB	Inside WXFB
Service Elevators							
3500	(1)	2 sp.	3'8"	5'4"x8'4"	5'0"x7'6"	5'4"x8'9 1/2"	5'0"x7'6"
4000	(2)	2 sp.	4'0"	5'8"x8'8"	5'4"x7'10"	5'8"x9'1 1/2"	5'4"x7'10"
4500	(2)	2 sp.	4'0"	5'10"x9'0"	5'6"x8'2"	5'10"x9'6"	5'6"x8'2"
5000	(3)	c/o	4'0"	6'8"x8'8"	6'4"x7'10"	6'8"x9'1 1/2"	6'4"x7'10"
Passenger Elevators							
2500	(4)	c/o	3'6"	7'0"x5'6"	6'8"x4'3"	7'0"x5'5"	6'8"x4'3"
3000	(5)	c/o	3'6"	7'0"x5'6"	6'8"x4'9"	7'0"x5'11"	6'8"x4'9"
3500	(6)	c/o	3'6"	7'0"x6'2"	6'8"x5'5"	7'0"x6'7"	6'8"x5'5"

(1) Listed as an industry standard hospital elevator for transporting beds, wheeled equipment, and passengers. This size elevator is almost obsolete and is recommended only where existing hoistway will not accommodate a larger elevator.

(2) Current standard size cars recommended for hospital beds, wheeled equipment, and passengers.

(3) Available. Applicable to hospitals where transportation of patients with traction frames attached cannot be conveniently accommodated by smaller standard elevators.

(4) Passenger elevator for light traffic.

(5) Passenger elevator for moderate traffic.

(6) Passenger elevator for heavy traffic. An industry standard that will accommodate a stretcher, or litter, 30 by 72 inches (will not handle a bed). Recommended for hospitals where other elevators are provided for transporting beds.

NOTE: Standard elevators listed herein are outlined in the Elevator Engineering Standards, July 1960 revision. 29/

The length of elevator cars supplied by some manufacturers may be about 1/4 to 1 inch more than shown above.

Table 7.--BED AND STRETCHER SIZES REPORTED BY VARIOUS MANUFACTURERS

BEDS	STRETCHERS
35" x 86"	22" x 72"
35 1/2" x 90" (orthopedic) without fracture frame	26" x 72"
35 1/2" x 93" (orthopedic) with fracture frame	26 3/4" x 74"
36" x 78" (old style)	27" x 74"
36" x 81"	30" x 72"
36" x 83 1/4"	
36" x 86"	
36 1/4" x 87 1/4"	
37" x 83"	
37" x 86"	
(High-Lo Bed: 32"high, 26" low)	

completely replaced, by telephones with dial intercommunicating connections. Voice intercommunication and associated signaling, incorporating recall and memory features, are applicable as parts of an integrated system of hospital communication. Nurses' call of buzzer-dome light signal type has been almost completely replaced by the audiovisual type. The use of closed-circuit television has been adapted to monitoring critically ill patients. Television along with voice communication is a convenient means for relatives or others to converse with patients who are in isolation. Television is also used for remote live viewing of surgical procedures and for diagnosis of X-ray or patients' condition by a specialist at remote locations. Some of the complicated surgical operations such as open heart and organ transplants would be almost impossible to perform successfully without the electronic means of communicating patients' condition to the surgical team. Pneumatic tube carrier systems provide a means of fast transportation of papers and other small lightweight articles. An integrated system, including as many as practicable of these communication services provided by one supplier, has certain installation and maintenance advantages over isolated systems by different suppliers.

Telephones

Interconnecting telephones should be provided for all department heads, assistants, operating and delivery suites, nurses' stations, offices, housekeeper, maintenance supervisors, doctors' rooms, record rooms, diet kitchens, and elevators. A telephone service outlet should be provided in the elevator shaft at mid-travel level for connection of the telephone in the elevator. All telephones may be connected on a dial system that will permit intercommunication without calling the hospital switchboard.

The practice of installing jacks in all patient areas for use of plug-in telephones is obsolete. Telephone instruments should be installed in all bedrooms for convenience of the staff in making this service immediately available for patients requesting and arranging for it. However, telephone jacks for use of portable telephones may be desirable in some wards and dayrooms.

Public telephones should be provided at convenient locations for visitors and others requiring the use of pay stations. At least one public telephone should be arranged so that wheelchair patients can use it.

Conduit should be installed for all telephone wiring. Surface wiring should be avoided to prevent a makeshift, dust-harboring appearance. Wire, equipment, and connections are usually provided by the telephone company.

Assistance in preliminary planning for telephone facilities may be found in reference 9. Assistance for detailed planning for telephone service can be obtained from local telephone companies.[30/] Most telephone companies are staffed with a communications planning service, which

should be utilized in planning and arranging for proper and adequate communications facilities. There is no charge for this service. The communications planning staff should be consulted in the early stages of construction planning so that the proper space and floor load-bearing strength can be provided for the equipment. Published information available from most local telephone companies is helpful in preliminary planning.

Intercommunication Systems

Intercommunication systems of the squawk-box type may contain a number of master stations and a number of remote stations for quick dispatch of instructions or communications within the area of the system. However, present hospital practice usually limits this type of communication to serving areas such as maintenance shop and food handling and preparation. A modified and improved offshoot of the squawk-box, or simple direct calling intercommunication-type equipment includes such features as memory, or registration of unanswered calls. This equipment is applicable to patient-nurse call systems or other communications throughout the hospital service areas.

Paging Systems

Two general types of paging systems are presently used in hospitals--loud speaker and radio, each used for different purposes entirely.

The loud-speaker system normally includes a microphone feeding through an amplifier to a number of speakers. The areas normally covered are large assembly halls, yard areas, or strategic locations for issuing instructions in case of fire or other catastrophe.

Radio paging is the system currently recommended for locating individuals or transmitting messages to individuals. The basic components of this system are: microphone--usually at telephone switchboard; radio transmitter--multi-channel placed at any suitable location; antenna system--may radiate in all directions, but usually a loop around the area of desired coverage; receivers--small lightweight-portable receivers tuned and set to receive on only one wave length, checked out to, and carried by, individuals (staff or selected visitors). Some systems transmit audible signals only, others transmit voice messages. All systems reported presently in use transmit one way only, that is, no talk-back features. However, use of transistors and careful design of receiver-microphone instruments may reduce the size and weight enough to make two-way voice transmission practicable and generally acceptable for hospitals.

Nurses' Call Systems

Call systems must be installed so that calls for nursing service may be registered by or for all patients. These call systems vary from the simplest type of a signal system to two-way voice communication and television. An important feature common to all systems is that the switch provided for patients' use will register the call at the nurses' station. This feature may be varied or amplified to fit any practical situation by the various types of switches for actuating calls and the various points and means of registering calls. For example, the switch may be either push- or pull-type to be operated by hand or elbow, or cheek, or foot-operated for patients who cannot use their hands. Bed-actuated switches which indicate that a patient has gotten out or fallen out of bed are available. Pull-cord-operated switches are preferable for isolation or contagious areas because these cords are inexpensive and may be removed and incinerated. A new cord can then be installed for each new patient.

Registration of calls should include a signal light in the corridor over the door of the room where the call originates and, except for single-bed rooms, at the calling station. A selection of lights, buzzers, bells, chimes, and annunciators is available for registering calls at the nurses' station, floor pantries, utility rooms, and all other duty stations.

Emergency call stations for actuating distinctive signals are usually installed in patients' toilet rooms and sometimes incorporated into the regular call station at the patient's bed for use by the nurse when she needs assistance. Call stations should be provided for nurses' use in nurseries, children's wards, psychiatric areas, operating, and delivery rooms.

Call stations installed in hazardous locations of anesthetizing areas must be explosionproof, and those installed in psychiatric areas may be activated by a key-operated switch located outside the door to an area, for use by the nurse or attendant.

Two-way voice communication is a feature which may be added to the signal system described. When, because of financial limitations, it is planned first to install a signal system and later to add the voice feature, conduits large enough to accommodate the wiring of the final installation should be included in the original installation.

Other sound services, in addition to the required nurses' call, are optionally being provided for patients' entertainment and information in many of the modern hospitals. These services include radio, recorded music and programs, and television; where these services are supplied together as a system, a cut-in feature for announcements should be included. When provided for in the planning, one speaker and one set of controls in a single enclosure may suffice for all these services. In this case, these systems should be supplied by and be the responsibility of one supplier for their satisfactory operation.

Radio

The radio is a source of noise frequently objectionable to some patients who wish to read or rest. However, the presence of radios in homes and in many work areas has so established their customary use that they are often demanded by many patients.

To eliminate the use of home-supplied radios of a variety of shapes, sizes, and undesirable connection arrangements, as well as possible sources of contamination, it is recommended that radio be provided by the hospital according to a planned system. The hospital should provide suitable facilities necessary for good radio reception. These normally include an outdoor AM-FM antenna with lightning arrester and a receiver-distribution system whereby commercial broadcasts, programmed music, and announcements may be distributed to the various receivers. Pillow-type speakers will minimize the disturbance to patients who do not wish to listen to radio programs. Consultation with reliable manufacturers of sound equipment may be helpful in determining the type and capacity of equipment to plan for the space requirements for housing the program amplifier, records, and other equipment.

Television—Entertainment.

Television has augmented radio as a source of news and entertainment in homes, hotels, and places of amusement, which has led to an increasing demand for television receivers in hospital patient areas.

To provide for good reception of commercial broadcasts of television programs is much more difficult than for radio programs. Terrain and structural materials between the sending and receiving stations may, in many cases, cause interference great enough to result in relatively poor reception for portable sets using only built-in or "rabbit-ear" antennas, such as those frequently supplied on a rental basis.

Where television is contemplated for patient areas, a carefully engineered system should be provided. This should include an outdoor antenna and coaxial cable lead-in fed through an amplifier to the individual receivers. Pillow-type speakers are recommended for all patient rooms even though they are single rooms, because the sound may be disturbing in other rooms.

Television—Monitoring

Closed circuit television is used in many hospitals. It is frequently used in operating rooms to transmit information to consulting doctors for advice and to students for teaching purposes. It is also used in cardiac catheterization procedures for displaying the X-ray image of the catheter position. It is sometimes used for the nurse to view children and for visitor-patient two-way view where patients are in isolation.

Visitor-patient television installations with audio provide an opportunity for children to communicate with parents where children are not permitted to visit the patient's rooms.

Television—Medical

The clinical applications of a medical television system in hospitals are principally for teaching and for consultations with specialists. Although a closed circuit TV system is generally recommended for medical television, serial broadcast on specially assigned wavelength between hospitals several miles apart has been used in a few cases where costs of installing conductors for a closed circuit system would be prohibitive or where such installation is impractical.

For televising surgical procedures as demonstrations, temporary equipment including a boom for holding the camera, has been used.

For permanent installation in surgeries, the camera should be adapted for use with the surgical light or located so as not to interfere with this light because most surgical lights are adjustable both for positioning and focusing. A gallery or adjacent room for a monitoring station and a view window for the operator are required.

A television system for ordinary teaching purposes, such as that of classroom illustrated lectures, may be provided by a much less expensive camera than that needed for live television of surgical procedures. Such a system could be operated for two distinct procedures: (1) making recordings locally or at some other institution; and (2) playback of recordings that are obtained from any available source.

The cost of purchasing, installing, and operating closed-circuit television systems has probably restricted their widespread use. However, numerous advancements have been made recently by organized groups and others interested in teaching and in the clinical applications of television in medicine and dentistry. Costs may be kept within reach by proper selection of equipment to meet specific needs. As an example of costs, television cameras are available for prices ranging from about $600 to $50,000, depending upon the quality of work required. Reasonably satisfactory results are being achieved in many instances by cameras priced at about $1,000 and less. Video tape recordings offer many advantages in teaching at a reasonable cost of equipment. Additional information on this subject may be obtained from the Institute for Advancement of Medical Commur cation. 31(a), (b), (c)/

Remote Dictation Service

Facilities are recommended for doctors dictate reports from a remote location. This wi be convenient for doctors and will permit mo efficient use of secretarial and typing service Facilities presently available for remote dictati may be provided by one of the following method

1. Utility telephone system equipment: Con nection to a recording device may be made throug the utility telephone dial service. 32/ This instru ment has recording facilities for a total record ing time of 2 hours for each recording drum. Tel ephone connection and disconnection starts an stops the recording instrument. Completion c the 2-hour total recordings is signaled throug the telephone receiver and is also indicated at th recording instrument. These dictations may the be transcribed for the signature of the doctor.

2. Recorders by commercial suppliers Dictation facilities may be provided wholly or in part by some of the commercial suppliers of such recording equipment as follows: (a) The complete assembly of recorders and private telephone system may be purchased by the hospital. In this case, dictation could be made from any of these telephones on the hospital premises but not over the utility telephone system. (b) Recorders may be purchased by the hospital from commercial suppliers and connected through a "Dial Dictation Trunk" supplied by the utility telephone system. In this case, dictation may be made from any connecting telephone of a utility system, local or remote.

Telautograph Transcribers

Telautograph transcribers which transmit written messages from one department to another are being used successfully in some hospitals. These systems have the advantage of leaving a written record of the message at the sending and receiving stations. Where installation of this equipment is contemplated, conduit should be installed for the necessary wiring. This equipment may be obtained on a rental or purchase agreement.

Pneumatic Carrier Tube Systems

Pneumatic tube systems are extremely useful to dispatch relatively small items such as records, prescriptions, or orders from one department to another. The carriers of these systems are propelled by electrically operated pressure systems, vacuum systems, or vacuum-pressure combinations. Dispatching of the carriers may be either by automatic or nonautomatic systems. Pneumatic systems for transmitting short written messages without a carrier are available.

Automatic routing of a carrier from one tube station to another tube station is accomplished by an electrical control system which directs the routing to the dropout at the selected station. Control contacts must be set at the sending station before a tube is dispatched.

In a nonautomatic system, all carriers dispatched from any remote station for delivery to any other remote station are dropped at the central station where they are manually redispatched by an attendant to the selected station.

The automatic system eliminates the need of a central dropout station, thereby saving time in routing and employees to reroute carriers.

Doctors' In-and-Out Registers

The doctors' in-and-out register system permits the doctor to register with a minimum of effort and delay by operating a switch adjacent to his name. Usually these registers include signal boards containing staff doctors' names or identifying numbers at all entrances normally used by doctors and at the telephone switchboard. All boards are electrically connected to register the same signal simultaneously. A recall feature may be included which consists of a flasher unit having a motor driven interrupter which actuates a flashing light at the doctor's name on all register boards. This feature assures the doctor's attention upon entering or leaving the hospital. The control for this unit is located at the telephone switchboard. The mechanics of registering in and out in hospitals equipped with radio paging are usually geared to the system established for check-in and check-out of the lightweight portable radio receivers.

Call-Back Systems

Call-back or return call systems provide a relatively inexpensive means of a "wake-up" or calling service for interns and nurses. Calls initiated in the office or at the switchboard actuate a bell or buzzer in the quarters. An answer switch is provided to acknowledge that the call has been received. Wiring may be arranged for individual calls or connected so that one button may call several rooms or stations simultaneously.

Fire Alarms

A manually operable interior fire alarm, arranged to sound audible alarms throughout the premises, including distinctive visual or audible alarm signals at each nurses' station, should be provided in every hospital as required by the Life Safety Code. 2(d)/

Presignal alarms calling for an investigation to determine that a fire actually exists before actuating the general alarm are not permitted in hospitals, because it is highly important that extinguishment procedures start without delay and before the fire spreads and becomes more difficult to control. It is preferable to respond to some false alarms than to a fire that has gained considerable headway because of a delay in notifying fire fighters.

Alarm signals should be distinctive in pitch and quality from other signaling devices. The alarm system should indicate the origin of the alarm at the telephone switchboard, boiler or engine rooms, fire brigade headquarters, administrator's office, nurses' home, and other appropriate locations.

In cooperation with the municipal fire department, arrangements should be made to transmit any hospital fire alarm automatically to the municipal fire department by direct connection to their fire alarm system or through another signaling service. Where such automatic signaling to the municipal fire department is not possible, provision should be made for prompt notification by telephone or by other means.

A fire alarm box is desirable near the main entrance of the hospital either at the telephone switchboard or in the administrative office.

Devices used in the alarm system should be listed by Underwriters' Laboratories, Inc. 33/ or Factory Mutual Laboratories, 34/ or certified to comply with the requirements of these listed devices. In all cases, the system should be electrically supervised, preferably the code signal type or visual indicator type, and should comply with NFPA No. 72. 2(g) or (h)/ One type of visual indicator consists of a board portraying the building or area plan on which small lamps indicate the area of the building from which the alarm signal was initiated.

Special Installations

Electroencephalographic suite.--Facilities for electroencephalographic (EEG) examinations may be required in some large hospitals.

An EEG diagnosis includes the measurement of electric potentials of the brain as measurable at the scalp. Because these potentials are extremely small, a highly sensitive instrument is required to detect and amplify the signals. To minimize unwanted pickup of static or other electrical disturbances with the wanted EEG information, special construction of the examining room may be required. 35, 36/

Medical electronics.--The use of electronic equipment in hospitals has increased tremendously in recent years, particularly during surgical and heart catheterization procedures, recovery, and in intensive care nursing areas. It is also used extensively for diagnostic purposes and in laboratories. To obtain maximum benefits from this equipment, proper space and facilities for use, storage, maintenance, and testing should be provided. 36/

To prevent gross waste of time, effort, space, and funds, consideration of procurement of electronic equipment should be based on advice and recommendations of a specialist qualified to use the equipment and interpret the data (preferably this person should be the one who will use the equipment); and also an assurance that an adequate staff of hospital people trained in the use of the equipment is available and will be maintained by the hospital.

Bactericidal lamps (ultraviolet).--Bactericidal, or ultraviolet, lamps are mentioned here for general information only, because they are used occasionally for specific functions in hospitals. They have been used in laboratories, ventilating systems, operating rooms, animal rooms, and in areas where tubercular patients are treated for control of airborne organisms. Direct and/or reflected radiation from these lamps is harmful to eyes and exposed skin of people, depending on the radiation intensity and exposure duration. Use of these lamps should not be contemplated unless the installation is carefully designed and proper maintenance is assured.

Bactericidal lamps producing ultraviolet energy in the range of 253.7 millimicrons wavelength are capable of destroying bacteria, mold, yeast, and virus. The amount of energy required to kill mold spores and bacteria varies considerably for each strain. 22, 37/ For example, 1,680 microwatt-seconds per cm^2 are lethal to some organisms while 19,700 are required to kill others; and to kill some of the mold spores, as much as 132,000 microwatt-seconds per cm^2 are required.

The penetration of 253.7 millimicron ultraviolet energy into opaque or particulate matter is so extremely small that organisms attached to airborne dust particles may survive in a radiation field when the dust particle shades the organism a sufficient part of the radiation exposure time. This characteristic of small penetration applies to lamps coated with dust. To be reliably effective, bactericidal lamps must be cleaned frequently or otherwise kept relatively free of dust. Bactericidal ultraviolet energy of sufficient concentration to kill the most virulent organisms within a reasonable time would be harmful to people unless their eyes and skin were protected. Use of ultraviolet lamps in hospitals is described in several reports. 37, 38, 39/

The use of ultraviolet light as means of reducing airborne bacteria is described in Air Filtration of Microbial Particles. 40/

Maintenance Shop

A carefully organized maintenance program is a necessary part of hospital service. An electric shop, well equipped with tools and supplies, is conducive to preventive maintenance and is most important in case of emergencies. Even a brief

lighting failure may cause annoyance and apprehension, and it invariably interferes with nursing services. Failure of operating room lights or essential equipment, such as therapeutic equipment and respirators, may have extremely serious consequences. No effort should be spared to minimize the occurrence of such failures and to be equipped to make the necessary repairs to restore service in the shortest time possible.

Tests and Inspections

After all wiring, switchboards, fixtures, and equipment are in place, they should be tested to determine that: (1) conductor insulation resistance is not less than that specified in the contract plans or required by the NEC; 2(a)/ (2) the system is free from short circuits or other faults; (3) motors start and rotate correctly; (4) lighting circuits are completely connected; (5) conductive floors are within specified resistance limits; (6) ground detector operates as specified; (7) all other equipment operates correctly and as specified.

The contractor should furnish to the owner a dated copy of all test readings, the name plate record of test instruments, and the name and title of person or persons who performed the tests.

Continual testing and inspections of all electrical installations are responsibilities of the hospital owner. Suitable meters should be readily available at the hospital at all times for measuring voltage and current within the normal range of the installations. Other meters should include an ohmmeter set complying with NFPA No. 56 recommendations for testing the resistance of conductive floors and furniture in anesthetizing areas, a shoe tester for testing conductive shoes on wearer, a light meter, and other meters as specifically needed. Methods of testing floors and equipment are described in NFPA Q58-6. 41/ Information on the selection and care of photometric instruments is provided in IES Transactions. 42/

Permanent Records

Legible plans and diagrams should be furnished to the hospital to indicate the location, size, and switching arrangement of all feeders and circuits, including the emergency power circuits. In a similar manner, record plans of all other electrical systems installed, such as nurses' call, paging, clock, and fire alarm should be furnished. Such plans and diagrams are highly valuable when repairs, alterations, or extensions of service are needed.

A complete set of descriptive bulletins, shop drawings, and operating and maintenance instructions for all equipment and controls should be assembled and indexed by the contractor and delivered to the owner.

REFERENCES

1. Codes and Standards of National Bureau of Standards, available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402:

   a. Handbook 30, National Electrical Safety Code.

   b. Handbook 48, Control and Removal of Radioactive Contamination in Laboratories.

   c. Handbook 49, Recommendations for Waste Disposal of Phosphorus-32 and Iodine-131 for Medical Uses.

   d. Handbook 51, Radiological Monitoring Methods and Instruments.

   e. Handbook 55, Protection Against Betatron-Synchrotron Radiations up to 100 Million Electron Volts.

   f. Handbook 59, Permissible Doses from External Sources of Ionizing Radiation.

   g. Handbook 63, Protection Against Neutron Radiation up to 30 Million Electron Volts.

   h. Handbook 65, Safe Handling of Bodies Containing Radioactive Isotopes.

   i. Handbook 72, Measurement of Neutron Flux and Spectra for Physical and Biological Applications.

   j. Handbook 73, Protection Against Radiation from Sealed Gamma Sources.

   k. Handbook 76, Medical X-ray Protection up to Three Million Volts.

   l. Handbook 80, A Manual of Radioactivity Procedures.

   m. Handbook 81, Safety Rules for the Installation and Maintenance of Electrical Supply and Communication Lines.

   n. Handbook 92, Safe Handling of Radioactive Materials.

2. Codes and Standards of the National Fire Protection Association, available from the National Fire Protection Association, 60 Batterymarch Street, Boston, Mass. 02110:

   a. NFPA No. 70, National Electrical Code.

   b. NFPA No. 56, Code for the Use of Flammable Anesthetics.

   c. NFPA No. 76, Standard for Essential Hospital Electrical Service.

   d. NFPA No. 101, Life Safety Code.

e. NFPA No. 78, Lightning Protection Code.

f. NFPA No. 75, Electronic Computer Data Processing Equipment.

g. NFPA No. 72, Proprietary Protective Signaling Systems.

h. NFPA No. 72C, Remote Station Protective Signaling Systems.

i. NFPA No. 77, Static Electricity.

j. NFPA No. 37, Standard for the Installation and Use of Combustion Engines and Gas Turbines.

3. Codes of the U.S.A. Standards Institute, 10 East 40th Street, New York, N.Y. 10016:

a. Elevators, Dumbwaiters, and Moving Walks, Safety Code for, A17.1-1960, and Supplement A17.1a.

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c. Electrical and Electronics Diagrams, Graphic Symbols for, Y32.2-1967.

d. Architectural and Electrical Layout Drawings, Graphic Electrical Wiring, Symbols for, Y32.9-1962.

e. Abbreviations for Scientific and Engineering Terms, U.S.A. Standard Z10.1-1941. American Society of Mechanical Engineers, New York, N.Y.

f. Preferred Voltage Ratings for A-C Systems and Equipment, Guide for, U.S.A. Standard C84.1-1954 (EEI R-6-1949) (IEC 38 and IEC 71).

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5. Guidelines for Installation of Emergency Electrical Systems in Hospitals. American Hospital Association, 840 North Lake Shore Drive, Chicago, Ill. 60611. S-37. 1967. 5 pp.

6. U.S. Department of Health, Education, and Welfare, Public Health Service. Fallout Protection for Hospitals, PHS Publication No. 930-D-23. U.S. Government Printing Office, Washington, D.C. 20402. March 1968. 27 pp.

7. Diesel Engines for Use with Generators to Supply Emergency and Short-Term Electric Power, Publication No. 1132. National Academy of Sciences - National Research Council, Washington, D.C. 1963. 25 pp.

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16. Biega, B. C. Recommendations for Hospital Operating Room Electrical Systems, AIEE District Conference Paper No. DP 62-662, presented at Great Lakes District Meeting, Fort Wayne, Ind. April 25-27, 1962. 11 pp.

17. The Simplex Manual. Simplex Wire and Cable Company, 79 Sidney Street, Cambridge, Mass. 02139. 1959. 503 pp.

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